

# Accuracy of Cone Beam Computed Tomography and Panoramic and Periapical Radiography for Detection of Apical Periodontitis

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## Abstract

The aim of this study was to evaluate the accuracy of imaging methods for detection of apical periodontitis (AP). Imaging records from a consecutive sample of 888 imaging exams of patients with endodontic infection (1508 teeth), including cone beam computed tomography (CBCT) and panoramic and periapical radiographs, were selected. Sensitivity, specificity, predictive values, and accuracy of periapical and panoramic radiographs were calculated. Receiver operating characteristic (ROC) analysis was performed to assess the diagnostic accuracy of the panoramic and periapical images. Prevalence of AP was significantly higher with CBCT. Overall sensitivity was 0.55 and 0.28 for periapical and panoramic radiographs, respectively. ROC curves and area under curve (AUC) with periapical radiography showed a high accuracy for the cutoff value of 5 for both periapical (AUC, 0.90) and panoramic (AUC, 0.84) radiographs. AP was correctly identified with conventional methods when showed advanced status. CBCT was proved to be accurate to identify AP. (*J Endod* 2008; 34:273–279)

## Key Words

Apical periodontitis, cone beam computed tomography, diagnostic imaging, endodontic diagnosis, radiography

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The diagnosis of apical periodontitis (AP) represents an essential strategy to determine the selection of an effective therapeutic protocol for endodontic infection control. AP is a consequence of root canal system infection, which can involve progressive stages of inflammation and changes of periapical bone structure, resulting in resorption identified as radiolucencies in radiographs (1).

Some studies have shown that a periapical lesion from endodontic infection might be present without being visible radiographically. The radiographic image corresponds to a 2-dimensional aspect of a 3-dimensional structure (2–5). Artificial lesions produced in cadavers can be detected by conventional radiography only if perforation, extensive destruction of the bone cortex on the outer surface, or erosion of the cortical bone from the inner surface is present. Lesions confined within the cancellous bone cannot be detected, whereas lesions with buccal and lingual cortical involvement produce distinct radiographic areas of rarefaction. To be visible radiographically, a periapical radiolucency should reach nearly 30%–50% of bone mineral loss (2, 3). Other conditions, such as apical morphologic variations, surrounding bone density, x-ray angulations, and radiographic contrast, also influence radiographic interpretation (6). An experimentally induced lesion might or might not be detected, depending on its location. A periapical lesion of a certain size can be detected in a region covered by a thin cortex, whereas the same size lesion will not be seen in a region covered by a thicker cortex. Lesion location in different types of bone influences the radiographic visualization (7).

A large number of studies with different diagnostic methods have evaluated the type and incidence of periapical lesions (8–11). Scientific consensus has been reached to the fact that AP is accurately identified by histologic analysis (10). On the other hand, it has been demonstrated that cone beam computed tomography (CBCT) can determine the difference in density between the cystic cavity content and the granulomatous tissue, favoring the choice for a noninvasive diagnosis (8, 11).

Several advanced radiographic techniques for the detection of bone lesions have been used in dentistry, namely digital radiography, densitometry methods, CBCT, magnetic resonance imaging, ultrasound, and nuclear techniques (7, 12–15). CBCT has been successfully used in endodontics with different goals, including study of root canal anatomy, external and internal macromorphology in 3-dimensional reconstruction of the teeth, evaluation of root canal preparation, obturation, retreatment, coronal microleakage, detection of bone lesions, and experimental endodontology (7, 12–18).

Few studies have compared the differences in AP image interpretation by using CBCT, conventional periapical radiography, or digital radiography. CBCT has provided promising results with a more accurate detection of AP (14, 16–18). The therapeutic protocol to treat diseases of endodontic origin has routinely been based on the evaluation of pathologic and clinical characteristics frequently complemented by radiographic findings. Radiographic imaging is the most commonly used diagnostic resource in endodontic diagnosis and treatment, and image distortions constitute a serious inconvenience. In addition, it is important to emphasize the limited number of endodontic epidemiologic studies. The knowledge of prevalence and severity of AP is often based on periapical radiography, whose accuracy is questionable.

**TABLE 1.** Prevalence of AP in Endodontically Treated and Untreated Teeth, Identified by Panoramic, Periapical, and CBCT Images (n = 1508)

	Panoramic	Periapical	CBCT	P value*
Treated teeth (n = 1425)				
Presence of AP	251 (17.6%)	503 (35.3%)	902 (63.3%)	<.001
Absence of AP	1174 (82.4%)	922 (64.7%)	523 (36.7%)	
Nontreated teeth (n = 83)				
Presence of AP	18 (21.7%)	30 (36.1%)	62 (74.7%)	<.001
Absence of AP	65 (78.3%)	53 (63.9%)	21 (25.3%)	

AP, apical periodontitis; CBCT, cone beam computed tomography.

\* $\chi^2$  test.

Therefore, considering some limitations on conventional radiography for detection of periapical bone lesions, advanced imaging methods such as CBCT might add benefits to endodontics and offer a higher quality on diagnosis, treatment planning, and prognosis. The purpose of this study was to determine the accuracy of CBCT imaging and panoramic and periapical radiographs on detection of AP.

**Materials and Methods**

**Patients**

Imaging exam records of 888 consecutive patients (59% female; mean age, 50 ± 12 years) including periapical and panoramic radiographs and CBCT were selected from databases from the Dental and Radiological Institute of Brasília (IORB, Brasília, DF, Brazil). Exams were obtained between May 2004 and August 2006. All patients had at least 1 tooth with history of secondary and primary endodontic infections, confirmed by clinical examination. A total of 1508 teeth were selected for the study, 523 molars, 597 premolars, 154 canines, and 234 incisors, and 94.5% of the sample had been treated endodontically. The study design was approved by the institutional Ethics in Research Committee.

**Imaging Methods and Analysis**

Panoramic radiographs were taken with a Veraviewepocs panoramic x-ray unit (J Morita Mfg Corp, Kyoto, Japan) with 0.5 mm × 0.5 mm tube focal spot and with Kodak dental films (T-MAT, 15X30; Manaus, AM, Brazil). The periapical radiographs were taken with Max S-1 x-ray equipment (J Morita Mfg Corp) with 0.8 mm × 0.8 mm tube focal spot and with Kodak Insight film (Eastman Kodak Co, Rochester, NY) according to the parallel radiographic technique. All films were processed in an automatic processor and developed by using standardized methods.

CBCT images were obtained with 3D Accuitomo XYZ Slice View Tomograph (model MCT-1; J Morita Mfg Corp) voxel size of 0.125 × 0.125 × 0.125 mm, 12 or 8 bits. Images were examined with specific software (3D tomo X version 1.0.51) in a PC workstation running under Microsoft Windows XP professional SP-1 (Microsoft Corp, Redmond, WA).

Three calibrated examiners performed visual analysis of all digital images, and the periapical index (PAI) by Ørstavik et al. (19) was used to determine the periapical status as follows: 1, normal periapical structures; 2, small changes in bone structure; 3, changes in bone structure with some mineral loss; 4, periodontitis with well-defined radiolucent area; 5, severe periodontitis with exacerbating features.

**Data Analysis**

Results of diagnostic radiographic methods were reported in frequency tables for the presence of AP, considering CBCT as the reference method. Sensitivity, specificity, predictive values, and accuracy of periapical and panoramic radiographs were calculated. Receiver operating characteristic (ROC) analysis was performed to assess the diagnostic accuracy of periapical and panoramic images in detecting AP. The level of interobserver agreement was assessed by kappa statistics in 10% of the sample.

**Results**

The prevalence of AP in both endodontically treated and untreated teeth, as identified by periapical and panoramic radiographs and dental CBCT, is shown in Table 1. The high discrepancy between imaging methods to detect AP indicated the possibility of false-negative diagnosis when using conventional radiography.

Table 2 summarizes the results of imaging diagnostic tests (periapical and panoramic) for the presence of periapical lesion diagnosed

**TABLE 2.** Results of Imaging Diagnostic Tests (periapical and panoramic) for the Presence of Periapical Lesion Diagnosed by CBCT as Standard Reference (n = 1508)

Teeth groups	CBCT	Periapical			Panoramic		
		Positive	Negative	Total	Positive	Negative	Total
All teeth	Positive	525	439	964	268	696	964
	Negative	8	536	544	1	543	544
	Total	533	975	1508	269	1239	1508
Incisors	Positive	86	74	160	26	134	160
	Negative	3	71	74	1	73	74
	Total	89	145	234	27	207	234
Canines	Positive	42	39	81	21	60	81
	Negative	0	73	73	0	73	73
	Total	42	112	154	21	133	154
Premolars	Positive	181	152	333	86	247	333
	Negative	4	260	264	0	264	264
	Total	185	412	597	86	511	597
Molars	Positive	216	174	390	133	255	388
	Negative	1	132	133	0	135	135
	Total	217	306	523	133	390	523

CBCT, cone beam computed tomography.

**TABLE 3.** Sensitivity, Specificity, PPV, NPV, and Diagnostic Accuracy (true positives + true negatives) for Periapical and Panoramic Exams, Considering All Examined Teeth and Teeth Groups

Method	Group of teeth	Sensitivity	Specificity	PPV	NPV	Accuracy
Periapical	All teeth	0.55	0.98	0.98	0.55	0.70
	Incisors	0.54	0.96	0.97	0.49	0.67
	Canines	0.52	1.00	1.00	0.65	0.75
	Premolar	0.54	0.99	0.98	0.63	0.74
	Molar	0.55	0.99	1.00	0.43	0.67
Panoramic	All teeth	0.28	1.00	0.99	0.44	0.54
	Incisors	0.16	0.99	0.96	0.35	0.42
	Canines	0.26	1.00	1.00	0.55	0.61
	Premolar	0.26	1.00	1.00	0.52	0.59
	Molar	0.34	1.00	1.00	0.35	0.51

PPV, positive predictive value; NPV, negative predictive value.

by CBCT as standard reference, considering all teeth together and each tooth group alone (incisors, canines, premolars, and molars). Data in Table 2 were used to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy (true positives + true negatives) for periapical and panoramic images (Table 3).

Overall sensitivity was 0.55 and 0.28 for periapical and panoramic radiographs, respectively, which indicates that AP was correctly identified in 54.5% of the cases with periapical radiographs and in 27.8% of the cases with panoramic radiographs. Minor changes in sensitivity were found for the different tooth groups, except for incisors in panoramic radiographs (0.16). High specificity values were found for all tooth groups, ranging from 0.96–1.00. Predictive values showed high probability of a positive diagnosis, indicating that a tooth actually had AP (PPV range, 0.96–1.00). NPVs were significantly lower, ranging from 0.35–0.65. This means a rather low probability of a negative diagnosis, indicating an actual absence of periapical lesion, particularly in incisors and molars with panoramic radiographs (0.35 and 0.35, respectively). Overall accuracy was 0.70 and 0.54 for periapical and panoramic radiographs, respectively. Accuracy of periapical radiographs was significantly higher than that of panoramic radiographs ( $P < .05$ ), which means that periapical radiographs were shown to be more accurate than panoramic to correctly identify or exclude the presence of a periapical lesion.

Table 4 shows the results of diagnostic tests with the PAI. A visual analysis of frequency distribution in Table 4 shows that CBCT tends to provide greater scores than periapical and panoramic radiographs, suggesting that diagnosis of AP graduation with conventional images is underrated in a great part of the cases. ROC curves and area under curve

(AUC) for different cutoff points with periapical radiography (Fig. 1) show that high accuracy is obtained in the cutoff value of 5 for both periapical (AUC, 0.90) and panoramic (AUC, 0.84) radiographs. ROC analysis, therefore, suggests that AP is correctly identified with conventional methods when it is in an advanced stage.

Kappa value for interobserver agreement considering the PAI scores ranged from 0.89–1.00 for periapical and panoramic radiographs and CBCT images.

### Discussion

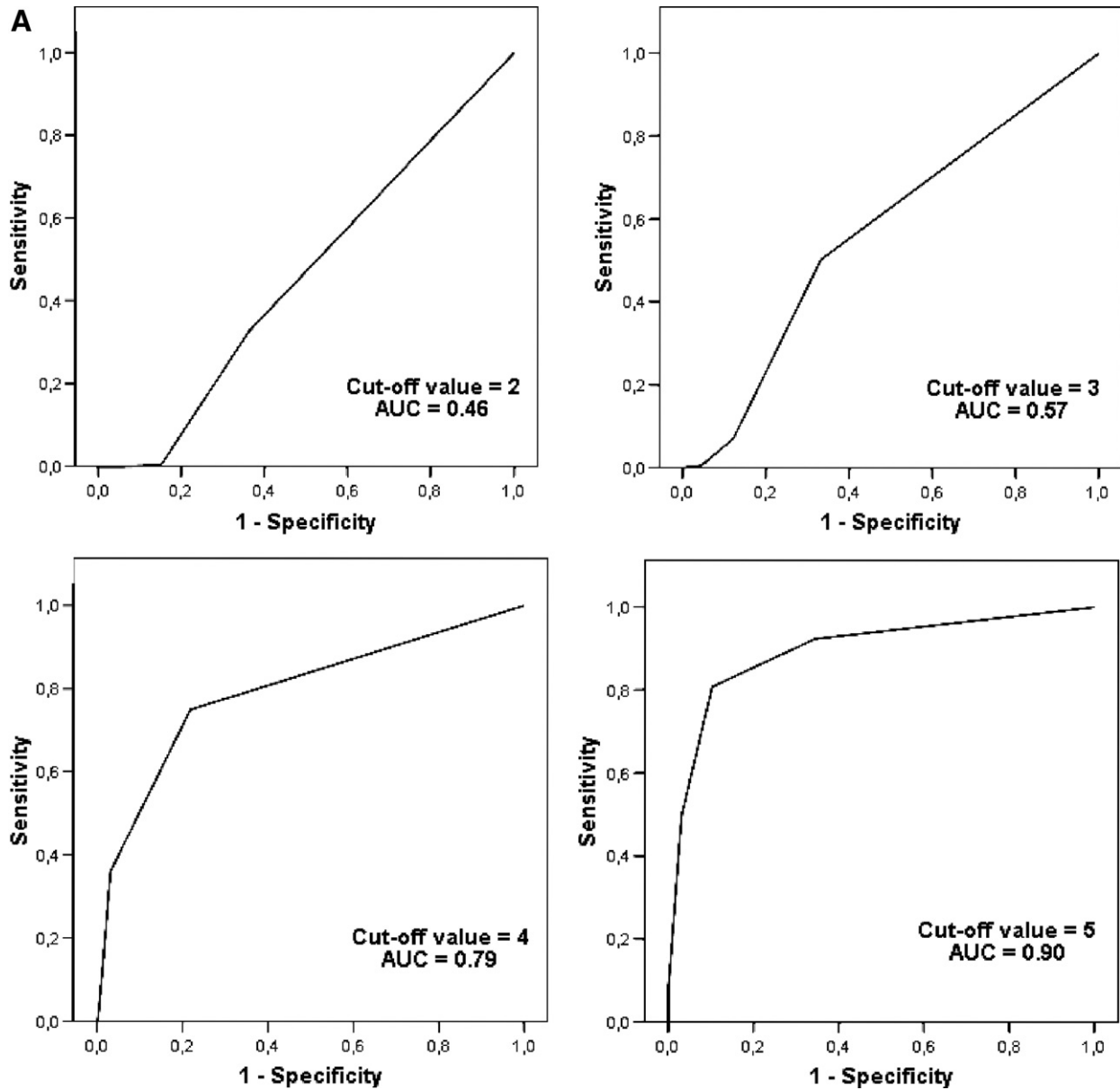
The findings of the present investigation demonstrated that the CBCT images present high accuracy for the detection of AP. CBCT images tend to offer greater scores than periapical and panoramic radiographs, suggesting that diagnosis of the graduation of AP with conventional images is frequently underestimated. AP was correctly identified in 54.5% of the cases with periapical radiographs (sensitivity, 0.55) and in 27.8% with panoramic radiographs (sensitivity, 0.28). Accuracy of periapical radiographs was significantly higher than that of panoramic radiographs ( $P < .05$ ). AP was correctly identified with conventional methods when a severe condition was present.

The results of this study are in agreement with those of previous investigations (14, 17). Cotton et al. (14) reported that the ability of cone beam volumetric tomography to assess an area of interest in 3 dimensions might benefit both novice and experienced clinicians alike. The advantages include increased accuracy, higher resolution, scan-time reduction, and lower radiation dose. Lofthag-Hansen et al. (17) compared intraoral periapical radiography with 3-dimensional images (3D Accutomo) for the diagnosis of periapical pathology in 36 patients

**TABLE 4.** Results of Imaging Diagnostic Tests with the PAI (n = 1508)

	CBCT					Total
	1	2	3	4	5	
Periapical						
1	536	248	93	96	2	975
2	8	119	81	149	3	360
3	0	1	12	92	8	113
4	0	0	1	46	11	58
5	0	0	0	0	2	2
Total	544	368	187	383	26	1508
Panoramic						
1	543	338	133	219	6	1239
2	1	30	51	95	4	181
3	0	0	3	51	6	60
4	0	0	0	18	9	27
5	0	0	0	0	1	1
Total	544	368	187	383	26	1508

PAI, periapical index; CBCT, cone beam computed tomography.



**Figure 1.** (A) ROC curves and AUC for different cutoff points with periapical radiographs. (B) ROC curves and AUC for different cutoff points with panoramic radiographs.

(46 teeth). When both diagnostic methods were analyzed by all observers, they agreed that the Accuitomo images provided clinically relevant additional information not found in the periapical films.

Velvart et al. (16) correlated the information gathered from standard dental radiography and high resolution CBCT scans to the findings obtained during surgery regarding the presence of endodontic lesions in 50 patients. All 78 lesions diagnosed during surgery were also visible with CBCT scans. In contrast, only 61 (78.2%) lesions were noted by conventional radiographs. The mandibular canal was identified in 31 radiographs, whereas the oblique cuts of the corresponding CBCT scans clearly showed the mandibular canal in all patients. In addition, the amount of cortical and cancellous bone, bone thickness, and the 3-dimensional extension of the lesion could only be adequately interpreted in the CBCT scans. Rohlin et al. (20) evaluated the diagnostic accuracy of panoramic and periapical radiographs and verified that periapical radiography was significantly superior for detection of sclerotic lesions

and all lesions in maxillary premolars and mandibular molars. Stavropoulos and Wenzel (21) verified the accuracy of CBCT (New Tom 3G; NewTom Germany, Marburg, Germany) and intraoral digital and conventional film radiography in mechanically created periapical defects in pig jaws. The results showed that the New Tom 3G has a higher sensitivity, PPV, and diagnostic accuracy than intraoral radiography (digital-Dixi2 or conventional radiography). No difference was observed between the 2 periapical (digital versus conventional) radiographic methods. von Stechow et al. (22) determined whether a 3-dimensional volumetric quantization of periradicular bone resorption could be achieved, and how this would correlate with 2-dimensional lesion area by histology. The results showed a significant correlation between lesion void volume and 2-dimensional lesion area by histology, as well as high correlations between void volume and void thickness and standard deviation of the void thickness, but no relationship with void surface. These results showed that 3-dimensional analysis of CBCT images is highly corre-

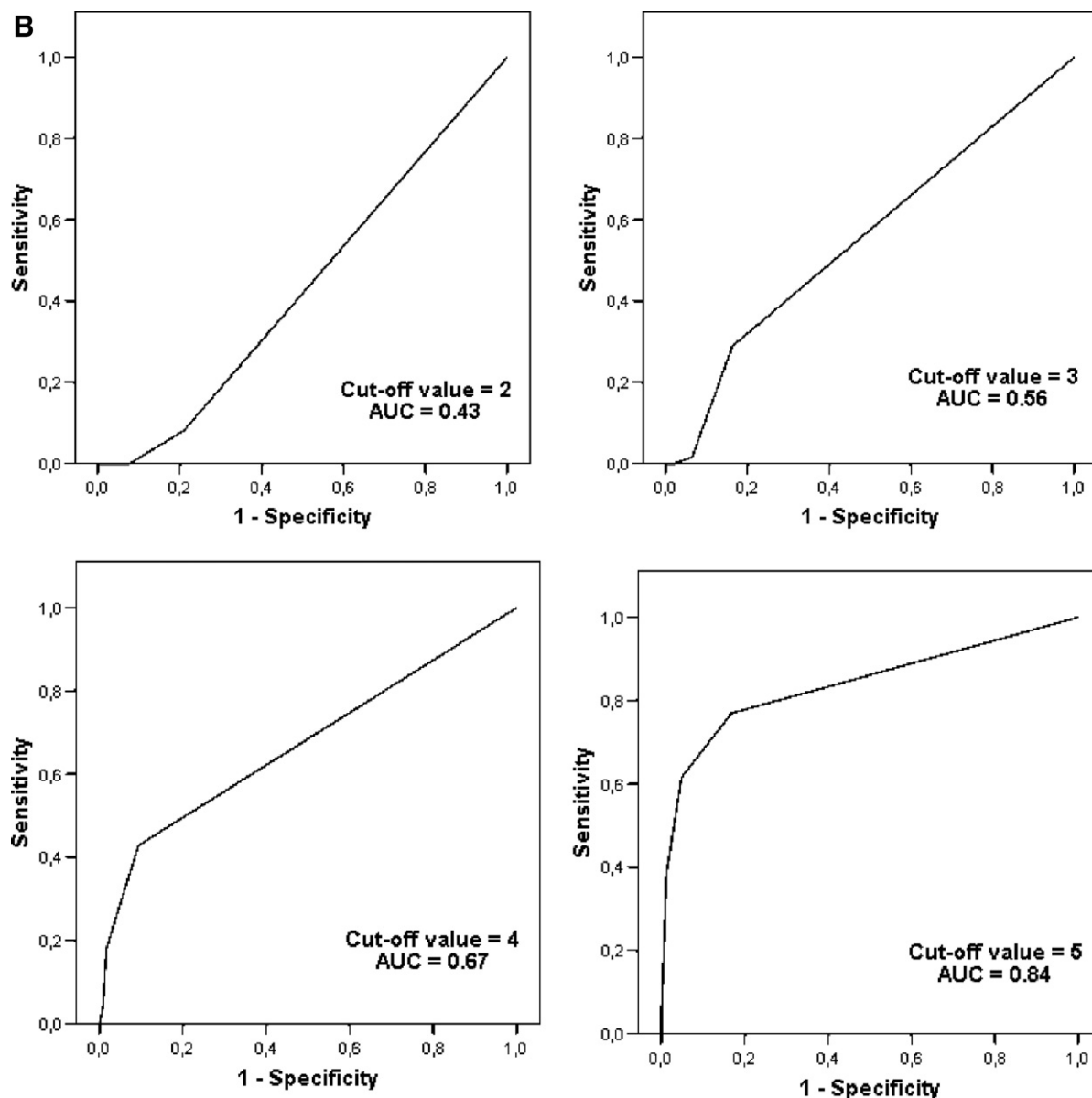


Figure 1. (Continued).

lated with 2-dimensional cross-sectional measures of periradicular lesions. Nevertheless, CBCT allows assessment of additional microstructural features as well as subregional analysis of lesion development.

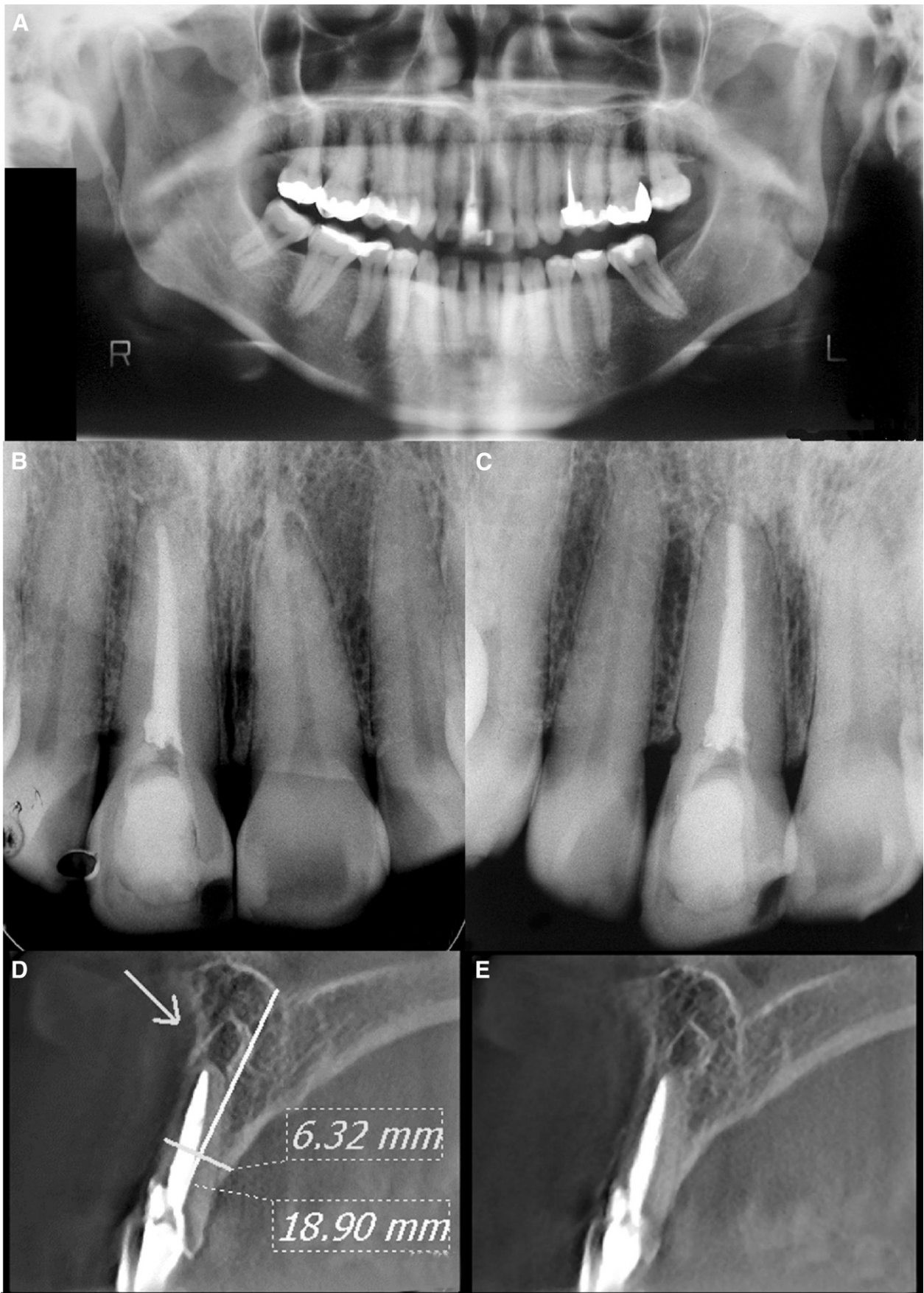
The likelihood of AP to exist and not to be identifiable by periapical or panoramic radiographs is considerably high (Fig. 2). The difficulty to accurately detect AP has been mentioned elsewhere (2, 3, 7, 19). One important aspect to be considered is that it is necessary to have approximately 30%–50% of mineral loss to visualize AP (2, 3). Morphologic variations of the apical region, bone density, x-ray angulations, radiographic contrast, and actual location of the periapical lesion will influence the radiographic interpretation (6, 23). The limitations of radiographic assessment as a study method should not be overlooked, mainly to reduce false-negative results.

According to the criteria and conditions described in methodology, kappa values for PAI scores ranged from 0.89–1.00 for periapical and panoramic radiographs and CBCT images. However, previous investigations, analyzing the interobserver agreement, had shown lower values (24, 25), and in other studies, higher ones were verified (range,

0.80–0.95) (26, 27). These results compared with other studies, such as Molven et al. (23), and occurred possibly as a function of the number of diagnostic groups and the frequency of diagnoses.

One of the scoring systems used in this investigation was the PAI described by Ørstavik et al. (19), which is the association of periapical lesion visualization on the basis of the radiographic aspects of the periodontal ligament. Its score system has been used in various research studies (27, 28).

Epidemiologic studies (26–28) in different populations have shown values from 20%–52% of AP prevalence in endodontically treated teeth identified by conventional periapical radiographs. These discrepancies were attributed to the following reasons: (1) lack of homogeneity of the populations that were compared; (2) lack of standardization on radiographic assessment methods; (3) use of teeth or individuals as referential; (4) quality of endodontic treatment rated by either general dentists or endodontists; and (5) different levels of endodontic practices (specialist, general clinician) and infection control in the different populations.



**Figure 2.** (A) Panoramic and (B, C) periapical radiographs show normal periapical area of the upper right incisor. AP can be seen in the CBCT (D, E).

In view of the limitations of periapical radiography to visualize AP, a review of epidemiologic studies should be undertaken considering the quality of periapical aspects offered by CBCT images. In addition, it will certainly reduce the influence on radiographic interpretation, with minor possibility of false-negative diagnosis. In the present study, AP prevalence in endodontically treated teeth, when comparing the panoramic and periapical radiographs and CBCT images, was 17.6%, 35.3%, and 63.3%, respectively ( $P < .001$ ). A considerable discrepancy can be observed among the imaging methods used to identify AP.

Another aspect to be considered is that regardless of the method used to obtain the radiographic image, care should be taken to avoid misinterpretation. Regarding CBCT images, the presence of intracanal metallic post might lead to equivocated interpretations as a result of artifact formation. Lofthag-Hansen et al. (17) reported that when metallic objects are present in either the tooth of interest or an adjacent one, artifacts can pose difficulties in the analyses of Accuitomo images. In these cases, periapical radiographs are helpful to complement the diagnosis.

The truth is that most dentists do not have CBCT equipment in their dental offices. Thus, during endodontic treatment, it is important to choose a radiographic technique that minimizes image distortions, such as cone parallel technique, to obtain a high level of reproducibility and increase the diagnostic accuracy of the imaging method.

The viability and cost-effectiveness of CBCT images in clinical routine should be weighed, considering the caution with radiation doses, because it is not in accordance with the standard dose recommended in some countries. It is important to remember that this study was done on the basis of databases from a radiologic institute.

A positive factor to use the CBCT is production of high-resolution images. The CBCT images provide clinicians with submillimeter spatial resolution images of high diagnostic quality with relatively short scanning times (10–70 seconds) and a radiation dose equivalent to that needed for 4–15 panoramic radiographs (29). However, image quality might vary according to CBCT source. The characteristics of the CBCT equipment used in this study (3D Accuitomo) were the following: floor space, 1.6 mm × 1.2 mm; sensor type II; voxel size, 0.125 mm; field of view, 4 × 3 cm; scan time, 17 seconds; no pulsed x-ray.

The use of conventional radiographic images for detection of AP should be done with care because of the high possibility of false-negative diagnosis. A great advantage of using CBCT in endodontics refers to its usefulness in aiding in the identification of periapical lesions and in a differential diagnosis with a noninvasive technique with high accuracy.

Under the tested conditions and within the limitations of this investigation, it might be concluded that the prevalence of AP was significantly higher with CBCT, in comparison to periapical and panoramic radiographs. AP was correctly identified in 54.5% of the cases with periapical radiographs and in 27.8% of the cases with panoramic radiographs. Minor changes in sensitivity were found for the different tooth groups, except for incisors in panoramic radiographs. ROC analysis suggests that AP is correctly identified with conventional methods when in an advanced stage. CBCT was proved an accurate diagnostic method to identify AP.

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